The effects of non-sex-biased shooting on some population characteristics of the Eastern Grey Kangaroo in the Murrurundi area, New South Wales

D. J. Shelly[1]

[1]Department of Land and Water Conservation, Cobra Street Office, P.O. Box 717 Dubbo, New South Wales 2830

ABSTRACT

Data obtained from two surveys conducted in the winters of 1986 and 1987 show that, for the study area, centred on the town of Murrurundi in the Upper Hunter Valley of New South Wales, non-sex-biased commercial shooting of the Eastern Grey Kangaroo *Macropus giganteus* did not greatly alter population age and sex structure compared with populations that were either non-commercially-shot or were protected from shooting. It was found, however, that shooting in general (whether commercial or non-commercial) decreased the presence of large pouch-young thus delaying the reproductive activity of a population compared to those protected from shooting.

Comparative shooting intensity was more important in its effect on local populations than the type of shooting that was conducted. Populations which experienced high shooting intensities (10% and above shot/year) tended to have fewer adult females than those populations undergoing moderate (5–10% shot/year) and low (0–5% shot/year) shooting intensities. There was no significant alteration in the proportion of young (out-of-pouch) age classes with changes in shooting intensity. However, the proportion of pouch-young significantly decreased with increases in shooting intensity from low to moderate levels. Data suggest that shooting intensity levels at more than 5% of a population per year markedly delay the reproductive activity of local populations.

Key words: Eastern Grey Kangaroo, Shooting regime, Age and sex structure, Shooting intensity.

INTRODUCTION

Improvement of pastures, the provision of permanent watering points in arid or unreliable rainfall zones, the development of crops and the changes to natural grazing lands by stock have generally created more favourable conditions for kangaroos than were originally present (Giles, undated [1982]). Thus numbers have increased and, in response to the demands of the agricultural industry for the containment of damage caused by kangaroos and to prevent the often inhumane practices of reducing populations through indiscriminate shooting, trapping, driving and poisoning, the Australian and state wildlife authorities have implemented kangaroo management programmes. All states follow the three main objectives of kangaroo management developed by the Council of Conservation Ministers (CONCOM) in 1981. These are as follows:

1. To maintain populations of all species of macropods over their natural range.
2. To contain their deleterious effect on pastoral and agricultural production; and
3. To ensure that the best possible use is made of the kangaroos taken in accord with the previous objectives.

The commercial kangaroo industry is the main tool in kangaroo management programmes. The number of kangaroos, by species, to be taken each year by the commercial kangaroo industry for each state, is set by the Commonwealth Government. This quota may be varied during the year, or from year to year. It is based on the estimated number of kangaroos in the commercial harvesting area and their potential rate of increase, with the aim of preventing further short-term rises in population size. These quotas also have to take into account the wishes of conservationists, agriculturalists and the kangaroo harvesting industry.

In New South Wales, the state has been divided by the National Parks and Wildlife Service into several management zones, each of which is allocated to a licensed fauna (kangaroo) dealer. These fauna dealers take and process the meat and/or skins of the kangaroos shot by the commercial shooters. Other fauna dealers, licensed to trade in skins only, may purchase skins in any of the zones (Shepherd and Giles, undated [1982]).

In New South Wales kangaroos are protected under the *National Parks and Wildlife Act, 1974.* This means that the taking, killing, processing and selling of kangaroos is prohibited except under licence. Licences may be issued to landholders in response to an application which has been examined by a district officer of the National Parks and Wildlife Service. This licence will specify the number of individuals of the particular species to be killed. The licence is known as an occupier's licence and is issued under Section 121 of the Act.

The landholder who has been granted a licence, and whose property lies within the designated commercial kangaroo harvesting zone, has three choices in taking the animals.

Firstly, he can shoot the animals himself but may not sell the meat or skins (known hereafter as non-commercial-shooting); secondly, he can apply for a trapper's licence which lets him sell the kangaroos he has shot; or thirdly, he can arrange for a licensed trapper (a commercial kangaroo shooter) to shoot the kangaroos.

The licensed trapper and the fauna dealers are required under the Fauna Protection Regulations within the *National Parks and Wildlife Act 1974* to keep detailed records of the kangaroos killed and accepted. Both trappers and dealers are required to forward their returns to the Service at regular intervals.

Previous studies have been made to see if commercial shooting (which in most cases selectively removes male animals) does in fact lower kangaroo population densities and alters a population's age and sex structure (Kirkpatrick 1974; Kirkpatrick 1980; Ovington [ed.] 1984). These studies, however, were based on comparison of kill data returns of commercial shooters with kill data taken from overall population samples but did not compare the results from non-biased commercial shooting or from non-commercial (recreational shooting). Also, these studies did not compare the characteristics from populations which had not been culled. The basis of the present study was to see if different shooting regimes (non-sex biased commercial shooting, non-commercial shooting, and no shooting) and intensities affects the population age and sex structure of Eastern Grey Kangaroos in an area.

METHODS

Observations were carried out during two successive winters (1986 and 1987), of numbers of Eastern Grey Kangaroos in broad age and sex classes within areas undergoing (1) commercial shooting and (2) non-commercial, [i.e., recreational] shooting as well as (3) areas where the population was protected from shooting.

While age and sex structures could be determined for the populations of kangaroos protected from shooting and those undergoing non-commercial shooting by the harvesting of a sample of animals, this method was rejected in order to gain the maximum amount of landholder access. Properties which had protected kangaroo populations certainly did not want animals killed in the name of research while several landholders wanted to keep kangaroos on their properties undisturbed until they were ready to begin culling so as to time their non-commercial-shooting to coincide with crop growth. Since data on kangaroo populations undergoing non-commercial shooting and those protected from shooting could not be acquired from any harvest records, observations of kangaroos in the field were necessary. Substantial changes in population age and sex structure may indicate over-harvesting, a state of affairs which may well constitute a threat to the continued existence of that population.

All the commercially-shot properties surveyed are located west to north-west of Murrurundi in the Upper Hunter Valley of New South Wales in commercial shooting zone no. 1, at distances from 5–60 km apart. Properties chosen were those regularly shot by the single professional kangaroo shooter, Max Young, operating in this district. Kill data returned to NPWS by Max Young showed a non-sexed-biased harvest (48.5% males c.f. 51.5% females between 1981 and 1987) over six properties. These properties are designated CS in Table 1. An area was chosen in the Murrurundi district where properties non-commercially-shot and those free of shooting were found in the same locality. Commercial shooting in this region is based solely on the Eastern Grey Kangaroo.

Fifty-four properties were selected as potential sites within an overall area of 2 500 sq km. Topographic maps of the area were used to select properties whose topography showed a combination of wooded slopes and partially-cleared land for grazing. It was considered that this would be the most likely habitat for Eastern Grey Kangaroos. Properties completely cleared for cultivation were rejected as were properties close to townships. The lack of suitable habitat and the presence of frequent disturbance respectively would, it was thought, tend to exclude the presence of a resident population of kangaroos. Twenty-nine of the property owners agreed to allow the survey, six conducting commercial shooting, 17 non-commercial shooting and six having no shooting taking place. Of the 2 500 sq km approximately 360 sq km were deemed to have unsuitable habitat for the Eastern Grey Kangaroo. The area covered by the properties surveyed totalled 37 820 ha. For each property surveyed, the following data were collected:

1. Sex and age classes of kangaroos observed while traversing a line transect on just one occasion.
2. Size of the property.
3. The length of time (years) shooting of kangaroos has taken place.
4. Whether the shooting, if any, is commercial or non-commercial.
5. The approximate number of kangaroos shot on the property per year in recent years (N.B. — only commercial shooters are legally required to keep records of all animals killed). Some non-commercial shooting was done under licence with the number of animals taken specified on the licence. Most properties, however, culled kangaroos without a licence hence, landowner estimates were needed.

Table 1. Individual Eastern Grey Kangaroo Population Density Estimates and Shooting Intensity Percentages, 1986–87.

Property No.	Estimated Kangaroo Density (kangaroo/ha)		% Population Estimate shot/year	
	1986	1987	1986	1987
CS 1	0.58	0.45	17.8	23.0
2	0.03	0.08	50.0	19.0
CS 3	0.45	—	21.0	—
CS 4	0.05	0.62	570.0*	42.0
5	0.50	0.05	5.0	56.0
6	1.11	0.16	9.0	58.0
7	0.19	0.48	14.0	6.0
CS 8	0.71	0.57	25.0	31.0
CS 9	0.56	0.37	11.0	17.0
10	0.91	0.25	2.0	7.0
11	0.31	0.21	10.0	16.0
12	0.83	0.27	0.0	0.0
CS 13	1.18	0.65	13.0	23.0
14	1.11	0.34	8.0	27.0
15	0.96	0.38	5.0	13.0
16	1.11	0.17	0.0	0.0
17	0.79	0.38	6.0	12.0
18	0.84	0.71	8.0	10.0
19	0.06	0.26	0.0	0.0
20	0.23	—	0.0	—
21	0.25	—	0.0	—
22	0.29	—	7.0	—
23	1.03	0.45	7.0	15.0
24	0.42	0.16	3.0	8.0
25	—	0.07	—	0.0
26		No Observations		
27		No Observations		
28	—	0.07	—	23.0
29		No Observations		

CS = Properties commercially-shot for the Eastern Grey Kangaroo.
* = Shooting had been conducted just prior to count. Therefore low numbers of kangaroos seen but high numbers shot over a year.

Winter months were chosen as the optimal time of year for survey as this is when commercial shooting for kangaroo furs is at its peak.

As well as the effects of shooting, natural environmental conditions also operate to regulate the density of local kangaroo populations (Kirkpatrick and McEnvoy 1966; Frith and Calaby 1969; Caughley, Bayliss and Giles 1984; Giles 1985; Rawlinson 1986). In order for age and sex structure of local populations to be able to reflect the influence of shooting, there is a need to standardise seasonal weather influences over the whole study area. Ideally, data from the two consecutive winter surveys should be combined in an attempt to smooth out any seasonal variation in kangaroo density. In the case of this study, it was found that there was no statisticallly significant difference (chi-square test at 5% level of probability) in the sex and age ratios found in the three shooting regimes between the two winter surveys, allowing data to be further combined to increase the data set for analysis. Data analysis on an individual property basis was not practical as the variation in numbers of Eastern Grey Kangaroos ranged from no animals observed, to a high of 61. Hence property data were grouped according to overall shooting regime.

The timing of the observations has the ability to cause differing results if surveys on the protected populations were conducted at different times of the year compared to those subjected to shooting, given that the Eastern Grey Kangaroo does show a seasonal breeding cycle. This theory, however, is not relevant in this case as the properties were surveyed at random and all sites were covered within a seven week period in order to negate changes to environmental conditions such as rainfall affecting pasture growth.

The following methods were used to estimate population numbers and structure:

Line transect observations

A single transect path (not necessarily a straight line) through a specific habitat-type (tree/pasture interface) was selected for each property visited. Transect lengths ranged from 1 500 m to 5 000 m according to the area of interface available. A single transect was chosen because the gradation from woodland or open forest to pasture usually occurs within a distance of 50–100 m. Observations over this range can be made from the one transect path, negating the need for multiple transect lines, which, for this particular purpose, would only cause duplication

of observations. Perpendicular distances recorded from the transect line to each observed kangaroo were measured by pacing and determined to the nearest metre. Given that the transect route would be a curved one through the tree/pasture habitat available, each transect path was broken into small adjacent straight line segments. Perpendicular distances were measured from the line segment from which observations were made.

All transects were traversed after 3.00 pm because studies and observation have shown that Eastern Grey Kangaroos, like most other macropods, rest through the day and become more active, and therefore visible in the late afternoon and at night (Caughley 1964; Kaufmann 1974; Lavery (ed) 1985). Thus a transect positioned along an extensive tree/pasture interface would have the advantage of being in an area of maximum macropod activity during late afternoons, so providing the best area for the direct observations of kangaroos.

Distance measurements were used in the calculation of relative population density estimates. Such estimates were needed in order to obtain comparative shooting intensity figures for the various populations surveyed (i.e., the percentage of a property's population estimate shot per year — see Table I). The relative population density estimates are not true reflections of whole property population size as the base data is obtained from the tree/pasture interface (a favoured macropod habitat). Therefore, values obtained by this method would be over-estimations of true population size. The use of this specific habitat's estimate coupled to the whole property kill data from the commercial shooters returns and landowner estimates, will, however, give a basis for comparison between shooting regimes, as the same extrapolation technique has been applied to all properties surveyed. Population sex and age structure can then be related to comparative shooting intensity as well as shooting regime.

The population density formula decided upon for use in this study was

N = nA/2LY (Johnson 1977) where:

N = estimated number of animals in census area

n = number of animals seen during the transect

L = length of census transect (m)

Y = mean right-angle distance (m)

A = area to be censused (ha)

Sex and age-classing techniques

Sex and age-classing of the Eastern Grey Kangaroos were carried out with the aid of 10 × 50 power binoculars. There was no sampling of populations by shooting for detailed age determination. Those classes utilized in this study were similar to those used by Croft (1981) for the Wallaroo *Macropus robustus* and are given below.

1. Adult male: sexually mature. Body weights 40–90 kg. Characterized by muscular development of upper arms. Usually the largest animals within a group. When moving, testicles are easily observed, allowing positive identification.
2. Adult female: sexually mature. Body weights 25–40 kg. No marked muscular development of upper arm. Adult females stand about three-quarters the size of an adult male. Any females observed with pouch-young or young-at-foot were included in this group. The presence of pouch-young was noted if the females pouch was observed to be visibly extended (therefore, this study was concerned only with aged pouch-young and not all the females which had young at early development stages).
3. Sub-adults (male and female): sexually immature. Body weights 15–30 kg (male) and 15–25 kg (female). Sub-adult females smaller than adult females and carry no young. Sub-adult males have no muscular development of upper arms. In size they stand to about one-half adult heights. In behaviour they act independently of adults.
4. Young-at-foot: Kangaroos permanently out of mother's pouch but still suckling. Weight range approximately 6–15 kg. Stand about one-third of adult height and keep close to adult female. Sex indistinguishable on external morphological characteristics.

Observations of sex and age were conducted concurrently with the counting of all observed Eastern Grey Kangaroos within tree/pastures interface when the transect was transversed. A total of 1 086 kangaroos were counted. However, only 565 were used in subsequent data analysis. Only individual animals positively identified as to sex and age class and groups of kangaroos in which all members were classed were utilized. These rules were applied in order to elimate error in age and sex classes associated with the presence of unidentified animals. The kangaroos of unidentified sex will affect the identified sex ratios because in some cases they were a significant proportion of the group.

There also exists the possibility of the rejection of an observation due to poor sightability not being independent of age and sex class. In response to this, sex classes for sub-adults were combined in order to eliminate difficulties in sex identification on immature animals. Since the majority of kangaroos are observed in mobs or family groups (Kaufmann 1974; Kirkpatrick 1966) the chances of not identifying specific age

Table 2. 1986–87 combined survey data for Eastern Grey Kangaroos distributed according to shooting regime. (Numbers of individuals counted in transects.)

	Commercially Shot Properties	Non-commercially Shot Properties	Non-shot Properties
Adult male	68	127	32
Adult female	55	143	42
Sub-adult	24	42	16
Young-at-foot	6	9	1
Large pouch-young*	8	26	15
Totals	153	321	91
% Adult	80.4	84.1	81.3
% Young	19.6	15.9	18.7
Pouch-young	5.2	8.7	16.5
% Male	44.4	39.6	35.2
% Female	36.0	44.6	46.2

* Pouch-young not included in the indicated totals.

Table 3. Chi-square tests on number of pouch-young cf. total kangaroos. 1986–87 combined survey on properties grouped according to shooting regime.

Comparison	Total No. of animals involved	Chi-quare value
Commercially-shot/Non-commercially-shot	508	1.57 N/S
Commercially-shot/Not shot	267	6.85 *
Non-commercially-shot/Not shot	455	3.57 N/S

N/S = No significant difference. * = Significant difference at 5% level.

classes of kangaroos is also minimal as most animals in a group are observed when found or when the mob moves away from the observer. Of the lone kangaroos observed in this study (7% of all observations), 46% were males and 35% were females with the remainder being either sub-adults or unidentified (cf. Kirkpatrick 1966: 35% of single animals being male, 38% female). Thus, there was an equal probability of finding lone animals of either sex, hence it can be assumed that unidentified animals are independent of age and sex class.

RESULTS AND DISCUSSION

Shooting regime and its effects on Eastern Grey Kangaroo population, age and sex structure

Kangaroo populations subject to non-sex-biased commercial shooting gave the highest frequency of young age classes ie. sub-adults and young-at-foot (see Table 2). Chi-squared analysis of the ratios showed that this proportion of adult/young was not significantly different from those in non-commercially-shot and protected populations at the 5% level of significance. However, the ratio of pouch-young observed in populations protected from shooting was found to be significantly higher than in those populations commercially-shot but not in non-commercially shot populations (see Table 3).

Populations protected from commercial shooting show more females than males (Table 2). The percentage found in my research are similar to those given by Bell (1972) and Southwell (1976). Non-commercially-shot populations showed a sex ratio that was closer to a 1:1 proportion but still with a female dominance. Populations subject to commercial kangaroo shooting had more males present than females. This result was explained as being partly due to this commercial shooter (Max Young) taking near equal ratios of females and males rather than a heavy male bias typical of most commercial kangaroo shooters (Kirkpatrick 1980; Lavery (ed) 1985). Examination of the kill data returned to the N.P.W.S. by Max Young showed that of over three thousand kangaroos shot between 1981 and 1987, 48.5% males and 51.5% females were harvested. A male-biased harvest would leave proportionally more females in the field to be observed but a harvest slightly biased towards females would leave proportionally more males in the field. Although the data in Table 2 showed differences in the percentages of males to females between protected populations and those undergoing commercial and non-commercial shooting, these differences were not statistically significant.

The data also suggest that:

- commercially-shot populations may have the greater proportion of young age classes as those populations show the highest percentage of young from the lowest percentage of adult females.

- populations of non-commercially-shot kangaroos and populations protected from shooting have similar percentages of adult females but the percentage of large pouch-young observed in protected populations is approximately double that of non-commercially-shot populations, and
- commercially-shot populations showed a lower percentage of adult females and therefore were likely to have a lower reproductive rate. This difference, however, seems to have been negated by the time the pouch-young have grown to sub-adults.

Several reasons can be put forward to explain the findings of more pouch-young observed in protected populations compared to those undergoing shooting of some kind. The low percentage of pouch-young in populations subject to shooting may reveal the effect of shooting lowering the number of adult females but more likely reflect shooting activities interfering with normal reproductive behaviour through disturbance. While it has been known for females to dump pouch-young on occasions of extreme harassment this is not considered a factor in shot populations as not *all* kangaroos would be shot at on any one property and not *all* adult females would be put under enough pressure to release pouch-young in their attempts to escape. However, there may exist the possibility of a functional response to stress from shooting disturbance that may act to either inhibit pouch-young development or lower pouch-young survival rates to some extent among populations subject to culling. Such a theory, unsubstantiated as it is, may help explain pouch-young differences between populations but does not explain why the proportions of sub-adult animals are similar between protected and shot kangaroo populations. With similar proportions of sub-adults in all three shooting treatment populations, one would also expect to find similar proportions of pouch-young.

While the timing of observations over each year may not explain the pouch-young to sub-adult differences between populations, the timing of the shooting activities to the observations may have some relevance. There may exist the possibility of populations subject to shooting increasing their breeding after shooting activities have ceased. For example, the commercial shooter may only shoot on any one property for several nights in a row or over a period of one to two weeks then move on to the next property when large kangaroos become scarce or that property's quota has been taken. Thus surviving females may respond by increasing breeding after the stress of shooting disturbance is over.

Similarly, non-commercial shooting may only take place when a crop is at its vulnerable early growth stages or may stop after harvest, giving several disturbance-free months for females to raise young. Thus, any observations taken during the shooting periods may reflect the possible stress/disturbance breeding "slowdown" noted with advanced pouch-young but, by the end of the year the proportion of joeys would increase to show up later in a relatively even ratio of sub-adult kangaroos being observed in populations across the shooting-protected spectrum.

This theory, while untested, could be confirmed with several population surveys conducted throughout the year(s) on the same property to obtain age and sex class data from before shooting, during shooting and after shooting periods.

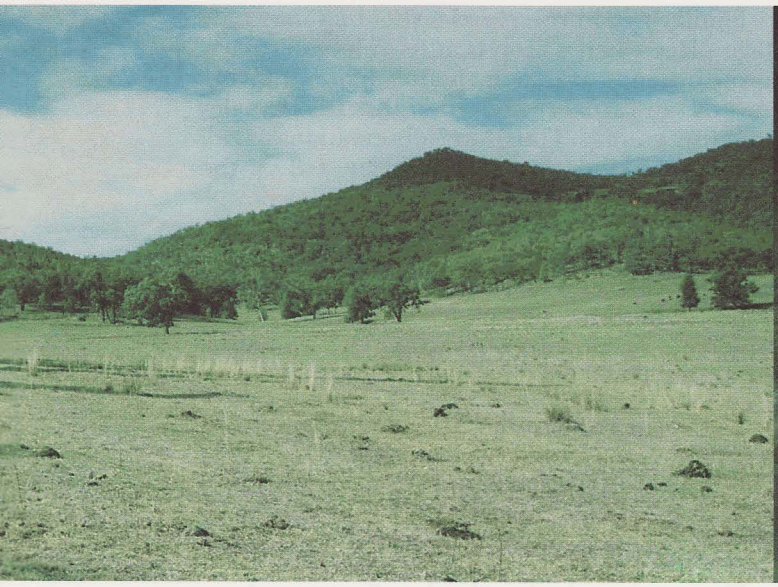
To examine whether the data for sex and age classes of protected populations from within the study area are indicative of protected populations in general comparative data were obtained in the Warrumbungle National Park in June 1989. 258 Eastern Grey Kangaroos were positively identified from small mobs and individuals and the resulting age and sex classes are given in Table 4.

Chi-square analysis showed no significant differences between the male/female, adult/young ratios or in the proportion of joeys in the populations. The closeness of the two sets of data suggest that any possible differences in population structure due to varying environmental conditions from the surveys being conducted in different years, or to the large distance between the two areas, were minimal in nature. Hence, it can be concluded with a reasonable degree of confidence that the age and sex classes observed in protected populations in the study area closely reflect the general trend.

The percentages of adult sexes and young in protected populations found in this survey closely resemble results found by several other studies. Bell (1972) classed 619 Eastern Grey Kangaroos on a North Queensland property with 30% being adult males, 48% adult females and 22% juveniles. Southwell (1976) found 33% adult males, 53% adult females and 14% juveniles in a sample of 205 Eastern Grey Kangaroos at Diamond Flat, New South Wales. This female dominance in protected populations was also found by Quin (1989) in a Victorian study and by Stuart-Dick and Higginbottom (1989).

Possible effects of shooting intensity on Eastern Grey Kangaroo population age and sex structure

To see if the relative amount of shooting affects population age and sex structure compared with the type of shooting conducted, the property



Above left: Typical kangaroo habitat: tree/pasture interface area near Bunnan, New South Wales. Photo D. Shelley.

Left centre: Observations of kangaroos can still be made in thick shrub cover but sexing animals is made difficult. Photo D. Shelley.

Below left: Female Eastern Grey Kangaroo in thick cover. Often animals in cover allow close approach before identifying danger. Photo D. Shelley.

Above right: Adult male Eastern Grey Kangaroo grazing on steep slope Scone, New South Wales. Note well developed forearms and chest which is characteristic of mature males. Photo D. Shelley.

Above centre: Only groups of kangaroos in which all animals were identified as to broad age and sex classes were used in this study analysis. Photo D. Shelley.

Table 4. Age and sex class divisions for protected Eastern Grey Kangaroo populations from the 1986–87 combined survey data and the Warrumbungle National Park, 1989. (Numbers of individuals).

	1986–87 combined survey	Warrumbungle National Park
Adult male	32	98
Adult female	42	125
Sub-adult	16	30
Young-at-foot	1	5
Pounch-young*	15	53
Totals	91	258
% Adult	81.3	86.6
% Young	18.7	13.4
% Pounch-young	16.5	20.5
% Male	35.2	38.0
% Female	46.2	48.5

*Pouch-young not included in the indicated totals.

Table 5. 1986–87 combined data for Eastern Grey Kangaroos distributed according to shooting intensity.

	0–5% population shot/year	5–10% population shot/year	>10% population shot/year
Adult male	32	76	111
Adult female	43	79	121
Sub-adult	15	28	39
Young-at-foot	1	8	7
Pouch-young*	16	11	25
Totals	91	191	278
% Adults	82.4	81.2	83.5
% Young	17.6	18.8	16.5
% Pouch-young	17.6	5.8	5.4
% Male	35.2	39.8	39.9
% Female	47.3	41.4	43.5

*Pouch-young not included in the indicated totals.

data were regrouped in terms of overall shooting intensity. The categories selected were those properties shooting 0–5%, 5–10% and 10% and above of their estimated Eastern Grey Kangaroo populations per year (hereafter referred to as low (LSI), medium (MSI) and high shooting intensity (HSI) categories respectively). Because the shooting intensity values are relating actual kangaroo numbers shot over the whole property to a population over-estimate based on animal density in a particular favoured habitat within a property, the true shooting intensity levels will most likely be even higher than those used in this comparative analysis. Thus the figures obtained for shooting intensity levels are not meant to be taken as indicative of what is actually happening on each property. The purpose of the study was to provide a basis for *comparison* of shooting levels between properties, which is why shooting intensity has been broadly classified as low, medium or high.

It was likely that changes in density (and hence possibly age and sex structure) would occur when over 10% of a local population was being shot per year over several years (N. Shepherd, pers. comm.). Thus, properties were grouped at 5% intervals in order to indentify such changes.

With a female-biased initial population, there would be a greater probability of shooting a female at any one time if shooting were non-selective. Therefore, in the short term, if shooting intensity were to increase, the *number* of adult females (but not the *proportion* of such females) in the population would decrease, subsequently causing the proportion of young age classes (as well as pouch-young) in the population to decrease.

Chi-square tests showed no significant differences (at the 5% probability level) in the ratios of adult and young animals between populations shot at low, medium or high intensity per year (see Table 5). Overall shooting intensity on adult kangaroos is assumed to be non-selective for age and sex. Whereas commercial shooting will be biased towards the larger, more visible individuals, the effects of the non-commercial shooting (recreational shooting) component in the shooting *intensity* classes will tend to offset this initial bias. Non-commercial shooting typically has the aim to remove numbers of animals at any one time thus kangaroos would be shot on an as-seen basis without regard to age and sex (with the possible exception of sub-adults and young-at-foot if the choice of several targets presented itself).

Table 6. Chi-square test on total kangaroos and pouch-young frequencies presented in Table 4. 1986–87 combined survey data on properties grouped according to shooting intensity.

Comparison	Total no. animals involved	Chi-square value
0–5% Population shot/year/ 5–10% Population shot/year	309	7.93*
0–5% Population shot/year/ >10% Population shot/year	410	3.95*
5–10% Population shot/year/ >10% Population shot/year	505	1.44 N/S

N/S = No significant difference. *= Significant difference at 5% level.

If a pre-shot population had more females than males present, more females than males would be taken out of the population by increasing the shooting intensity. This reduction in the number of females will decrease the population's reproductive capacity and hence lessen the proportion of young age classes in the population. The similarity of the adult/young ratios for populations in the three shooting intensity categories may mean that the relative shooting intensity on populations has not been consistent or conducted for long enough to produce any marked differentiation.

Within the study area, landholders claimed to shoot similar numbers of animals each year regardless of the actual kangaroo density present on the property at the time. Thus, landholders may be shooting a varying percentage of their property's population each season which may put that property's data into a different shooting intensity category for each season. Such possible seasonal differences in relative shooting intensity could act to mask any long-term differences in age and sex structure of local kangaroo populations.

While the expected decline in the proportion of young age classes in populations with increasing shooting intensity was not revealed in Table 5, such an expectation is satisfied in the proportion of pouch-young observed. Populations experiencing a low shooting intensity had significantly higher proportions of visible pouch-young present than those populations subject to medium and high shooting intensity levels (see Table 6). There were no significant differences in the proportion of pouch-young observed between populations shot at a medium and high shooting intensity. Thus it seems that shooting does lower the number of visible pouch-young in a population, probably through some form of stress factor that lessens pouch-young survival or alters the timing of reproduction. The removal of adult females does not seem to be related to the lowering of the numbers of pouch-young as the gross differences in the percentage of adult females in both shooting regime and shooting intensity categories were not significant.

One reason why the proportion of young age-classes remain relatively constant with changes in shooting intensity while the proportion of pouch-young declines is probably due to the attitude of the shooters involved. Most hunters, whether commercial or non-commercial, show a reluctance to shoot young kangaroos if larger, more numerous targets are present, even if their objective is to reduce numbers to a minimum. The number of pouch-young, however, is directly linked to the number of adult females, thus the more females shot the fewer pouch-young will be present.

As was stated earlier, the frequencies of males and females were not significantly different between populations in the three shooting intensity categories over both years. However, those populations shot at a low intensity showed the greatest percentage difference between males and females, with 12% more females, while those experiencing medium shooting intensity levels had only 1.6% more females than males. Populations shot at a high intensity showed 3.6% more females than males (see Table 5). Thus the tendency may be for sex ratios to even out with the onset of shooting upon a population. There seems to be no significant alteration in sex ratios with any increase in shooting intensity above the 5% (low) per annum level.

CONCLUSIONS

In terms of kangaroo management, the results suggest that if commercial kangaroo harvesting is to achieve its stated aims of controlling populations and containing deleterious effects on crop land and pasture, then a balanced harvest may be more effective than the present one in which more males than females are taken. An equal harvest of females and males will still lower the population by the same overall number of animals as well as having the benefit of delaying the reproductive potential of the remaining population. The data also indicate that kangaroo management may be rendered more efficient by the manipulation of overall shooting intensity levels (commercial and non-commercial shooting combined) on kangaroo populations at local or even regional levels.

The results indicate that at some level of shooting intensity (in this study 5% and more of the estimated population per year), there is a significant initial drop in reproductive capability even though significant losses of adult females may not occur. Such a reproductive capability drop may be only of a limited timespan and could be related to a stress-related factor inhibiting pouch-young development for the duration of shooting-related activities. Further research is needed to substantiate this claim.

ACKNOWLEDGEMENTS

The author is most grateful for the supervision given by Dr John Turner of the University of Newcastle Geography Department and to Messrs S. Reilly, R. Petronio and D. Wilks for their assistance in the fieldwork. Thanks must also go to the landholders of all the properties concerned and to Mr Max Young, the commercial kangaroo shooter who arranged for me to survey the properties over which he shoots. Lyndall Dawson and the selected referees must also receive recognition for their assistance in shaping this manuscript.

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